Homemade chemists

Michelle Francl wonders if home labs make (better) chemists.

When I was a graduate student, I spent a couple of weekends doing analytical chemistry in a rented garage sandwiched between a motorcycle repair outfit and a custom surfboard designer. Rather like a young classical musician who sneaks out of the conservatory to moonlight with a well-worn jazz quartet in a smoky basement club, I quickly shucked the careful habits inculcated in my university's shiny, well-stocked teaching labs and learned to improvise. No pipette bulbs? I bumbled around until I mastered the art of pulling up a sample in a pipette with one smooth breath.

This was not my first foray into improvisational chemistry. Years before, my brother Pat and I had set up a clandestine lab in a basement bathroom, hoping my mother would not notice the supplies we had liberated from her kitchen — or Pat's singed eyebrows after a sample of an evolved gas tested explosively positive for hydrogen. I may be a staid theorist these days, but both experiences left me with an enduring taste for the pleasures that could be found outside of the well supplied — but tightly supervised — confines of the chemistry teaching lab.

I'm certainly not the only chemist whose excitement for the field was first stoked in hole-in-the-wall labs. In his memoir, *Uncle Tungsten*, Oliver Sacks[1] wistfully chronicles his early love affair with chemistry, its sounds, its colours and its smells: the plonk of sintered tungsten to which nothing else quite compared, the deep azure of Fehling's solution on his father's dispensary shelves and the stench of hydrogen selenide that put brimstone to shame.

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The *Uncle Tungsten* trope — the notion that early experiments with dangerous chemicals puts youngsters on a path to becoming scientists — is an old one. More than a century before Baby Einstein began marketing the benefits of early exposure to science, the editor of *Boys' Miscellany* hoped in his introduction to a series[2] published in 1863, The Young Chemist, that

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the experiments would not only amuse, but equally well "result in the development of the embryo genius of a Liebig, a Davy or a Faraday." The cover (pictured) of a 1937 manual accompanying a child's chemistry set sounds a similar theme; it shows a young boy playing with the kit, his shadow an adult scientist in the same pose. My own experiences with 'out-of-the-box' chemistry notwithstanding, I wonder if there is any evidence that risky chemistry in particular creates chemists, or whether it is simply 'sharp nostalgia' for what we already possess — minds so curious that hazards pose no obstacle?

An afternoon's exploring of the Beckman Center for the History of Chemistry's collection of recreational chemistry sets (one of the largest in the world with more than 110 sets dating from 1917) makes it clear that the experiments children were encouraged to undertake were certainly more complex, and often riskier, in times past. Although the limited advice[3] about safety in early twentieth-century chemistry kits — "always remove a test tube from the flame before smelling at the mouth of the tube" — would seem cavalier to any instructor today, they simply reflect a similar sense of what constituted reasonable risk and good practice in academic and industrial settings at the time. The older sets held samples that would now be under lock and key in many research labs, including a mid-1950s kit that once held a sample of uranium ore dust. And just in case the budding young chemist is unsure of what to do with this treasure trove of materials, the accompanying manuals explain in detail how to synthesize enough chlorine gas to appreciate its characteristic odour or how to make ammonia gas by warming equal parts of calcium oxide and ammonium chloride in your palm[4]. Do wash your hands afterwards.

These days, there is virtually nothing in a commercial chemistry set you couldn't safely feed the family cat, and the prevailing image of the occupant of a basement chemistry lab is more likely to be that of some punk making illegal drugs than a budding Nobel Prize winner. I'm intrigued with the ever-widening gap between the level and complexity of chemistry done at home and the chemistry done in an industrial or academic lab — and wonder if we are wise to so scrupulously circumscribe the practice of chemistry. Are we being so vigilant with regard to safety that we have inadvertently deprived a generation of potential chemists of pivotal, if not necessarily essential, experiences?

The plural of anecdote isn't data, but there is a long history of research that supports the notion that chemistry sets, although perhaps not a necessary condition for creating chemists, are a contributing factor. More than a quarter of the young winners of a 1961 international science fair report that out-of-the-classroom experiences are what got them interested in science[5]. Half of the parents of the entrants in the 1960 Westinghouse Science Talent Search explicitly cited chemistry sets as significantly contributing to their teens' scientific interest and expertise[6]. More recently, a study following students from elementary school through secondary school showed a strong correlation between a continuing interest in science and children's early engagement with science outside of an instructional setting[7].

In earlier centuries, the ability to distil and compound simple drugs at home was

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The ultimate in domestic chemistry — the bench, as he last left it, at Thomas Edison's laboratory in his winter home in Florida.

considered a valuable skill, sought out by your neighbours. (Nowadays amateur chemists' neighbours are more likely to report them to local law enforcement.) Those domestic labs proved to be fertile ground for key developments in modern chemistry. The colour change in syrup of violets — a once common remedy for sore throats — which is the basis for Robert Boyle's method for reliably classifying materials as members of the acid or alkali 'tribes' was also documented in the contemporary herbalist and physician Hannah Woolley's notes[8]. Nobelist Irving Langmuir pointed to Agnes Pockels, who worked in a laboratory improvised in her kitchen, as one of the pioneers of surface chemistry[9].

Pockels, shut out of the academic laboratory, built what Lord Rayleigh called her 'homely appliances' to make quantitative measurements of surface tension[10]. Part of the pleasure of doing lab work at home, both when I was a kid and now, was figuring out work-arounds and constructing my own apparatus, such as a simple but effective test-tube holder made from a brown paper grocery bag. The work that it requires at times to get results with awkward, outdated or jury-rigged equipment fosters a patient tenacity that I suspect pays later dividends in the field or research laboratory — even for a computational chemist.

These are experiences that can be hard to replicate in a university teaching lab, where efficient movement of clumps of students through an exercise to a particular result in a fixed period is the desired (and often necessary) goal. I wonder, though, if we would compromise students' education if their labs didn't work smoothly for an entire term? One year I decided to do the experiment. I tossed out my rather standard physical chemistry lab curriculum and instead set my students to constructing a dye laser based on material from an amateur laser website[11]. Twelve weeks later we'd built (and rebuilt) a pump system, discharged a home-built capacitor with a memorable and satisfying bang, learned to fire-polish glass tubing and made endless mid-laboratory excursions to the local hardware store. The students ended the semester with a wealth of experience, though not with a reliably working laser. Yet, two-thirds of those students went on to do graduate work in science, a result I'd rather have than the two dozen measurements of the heat of formation of naphthalene I could otherwise have relied on them to produce.

As Pat and I discovered, *ad hoc* chemistry has its risks, but so does playing football and riding a bike, activities few parents would discourage. There are roughly 700 reportable chemical accidents in domestic settings each year in the US[12] (not counting incidents related to the synthesis of illegal drugs). Still, most of these incidents were not the result of some amateur chemist blowing up a clandestine lab, but the result of overzealous housekeeping. Mixing bleach with ammonia — or acids or pesticides or herbicides — doesn't make it stronger, but it can kill you.

Recreational chemistry kits and early laboratory exercises often make use of innocuous household materials, arguably reducing the risk of litigation, and making waste disposal trivial. But in doing so are we unwittingly giving the impression that chemistry is perfectly safe, that gloves, goggles and lab aprons are costumes, not protective gear? If you never encounter a problem when mixing up kitchen chemicals such as yeast, dish detergent and hydrogen peroxide, will it occur to you that other household materials cannot be mixed with impunity and poured down the drain? And as students move on to riskier protocols in upper division and research labs, without experiences that bridge the gap between utterly safe and hazardous, do they proceed without an appropriate sense of caution? Although school curricula are unlikely to change, we could do more to encourage amateur chemistry, and the safer, more persistent chemists it could create.

Although it's tempting to perform a risk-benefit analysis on chemistry sets and their potential to support the development of appropriately cautious and patient chemists, I admit part of the attraction is the risk, apart from any benefit. Risk is exhilarating. When quantum mechanics seemed poised to inexorably remake chemistry in the image of physics, Oliver Sacks lost his taste for the subject and turned his attention towards the practice of medicine. The ethereal world of atoms and bonds seemed less enticing than the pops and hisses of hands-on chemistry. Sacks may be nostalgic for his chemical boyhood, but secondary school students in the UK report that they, too, would like more practical — and exciting — work as they progress in their chemistry studies[13]. Are we losing potential chemists, not to physics or medicine, but to the X-games? ❐

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